

This item was submitted to [Loughborough's Research Repository](#) by the author.
Items in Figshare are protected by copyright, with all rights reserved, unless otherwise indicated.

The teaching and learning of technology for design

PLEASE CITE THE PUBLISHED VERSION

PUBLISHER

© DATA

LICENCE

CC BY-NC-ND 4.0

REPOSITORY RECORD

Norman, E.W.L.. 2019. "The Teaching and Learning of Technology for Design". figshare.
<https://hdl.handle.net/2134/3442>.

This item was submitted to Loughborough's Institutional Repository by the author and is made available under the following Creative Commons Licence conditions.



For the full text of this licence, please go to:
<http://creativecommons.org/licenses/by-nc-nd/2.5/>

The Teaching and Learning of Technology for Design

Eddie Norman

Senior Lecturer, Department of Design and Technology, Loughborough University and Co-Director IDATER

Biographical notes

Eddie Norman M.A., M.Sc., P.G.C.E., Sen.M.Weld.I. is a Senior Lecturer in the Department of Design and Technology at Loughborough University and Co-Director of IDATER. Secondary experience was gained teaching Technical Studies at Felsted School, Essex and Aylesbury Grammar School. Industrial experience was as a Research Engineer at The Welding Institute. His teaching and research interests centre on the use of technology in designing with numerous associated publications. He co-authored the textbook *Advanced Design and Technology*, edited a book for teachers *Teaching Design and Technology 5–16*, was co-author of a video series for Key Stage 3 design and technology, was Chief Editor of the magazine *New Designer* for Key Stage 4 students and, most recently, completed a resource pack for Key Stage 3 on Kites.

Abstract

This paper presents a non-linear model of design and technology that illustrates the concept of technology for design. Technology's relationship with science is discussed and research evidence concerning the emergence of new technology for a polymer acoustic guitar is described. This demonstrates the existence of knowledge, skills and values that are derived from designing and making rather than science. Learning 'by doing' and teaching 'by showing' and their pedagogical implications are discussed. Examples are given from the author's teaching of undergraduates and from a resource pack on kite design and technology for Key Stage 3. The paper shows the importance of sustaining designing and making in the next century.

Key words

Models, technology, design, teaching, learning, guitar

Technology for design was discussed as the summation of the knowledge, skills and values employed when designing in a paper published by the author in 1998 (Norman, 1998). A visual representation of this theoretical position is shown in Figure 1. 'Technology for design' is shown as three strands of a cord surrounding a model of designing. This model of designing was proposed and discussed by Roberts (1992). The ways in which theoretical models of design and technology can influence research outcomes was discussed in Roberts and Norman (1999) and it is essential to make clear the tradition within which you stand. The origins of the model in Figure 1 could be traced to the work of the APU (Hicks *et al*, 1982) and earlier to the *Design in General Education Project* completed at the Royal College of Art (Archer *et al*, 1979).

It is an important realisation that 'technology for design' is not another name for applied science. It is not simply science recontextualised (Layton, 1993). Technology has a symbiotic relationship with science; technological developments often preceding their scientific explanation. This has vital implications for the development of design and technology curricula, where (at least in the UK) programmes of study often refer to the *application* of knowledge taught and learnt in other subjects, notably science and mathematics. Such formulations of design and technology curricula seem to have lost sight of the fundamental role of 'craft-based' teaching (and learning) in technological

development. If a technological development is to proceed its scientific explanation, then there must be other ways of knowing (and teaching) that can bring this about. This paper describes research evidence relating to this theoretical position and provides examples of its pedagogical significance from the author's practice as a teacher.

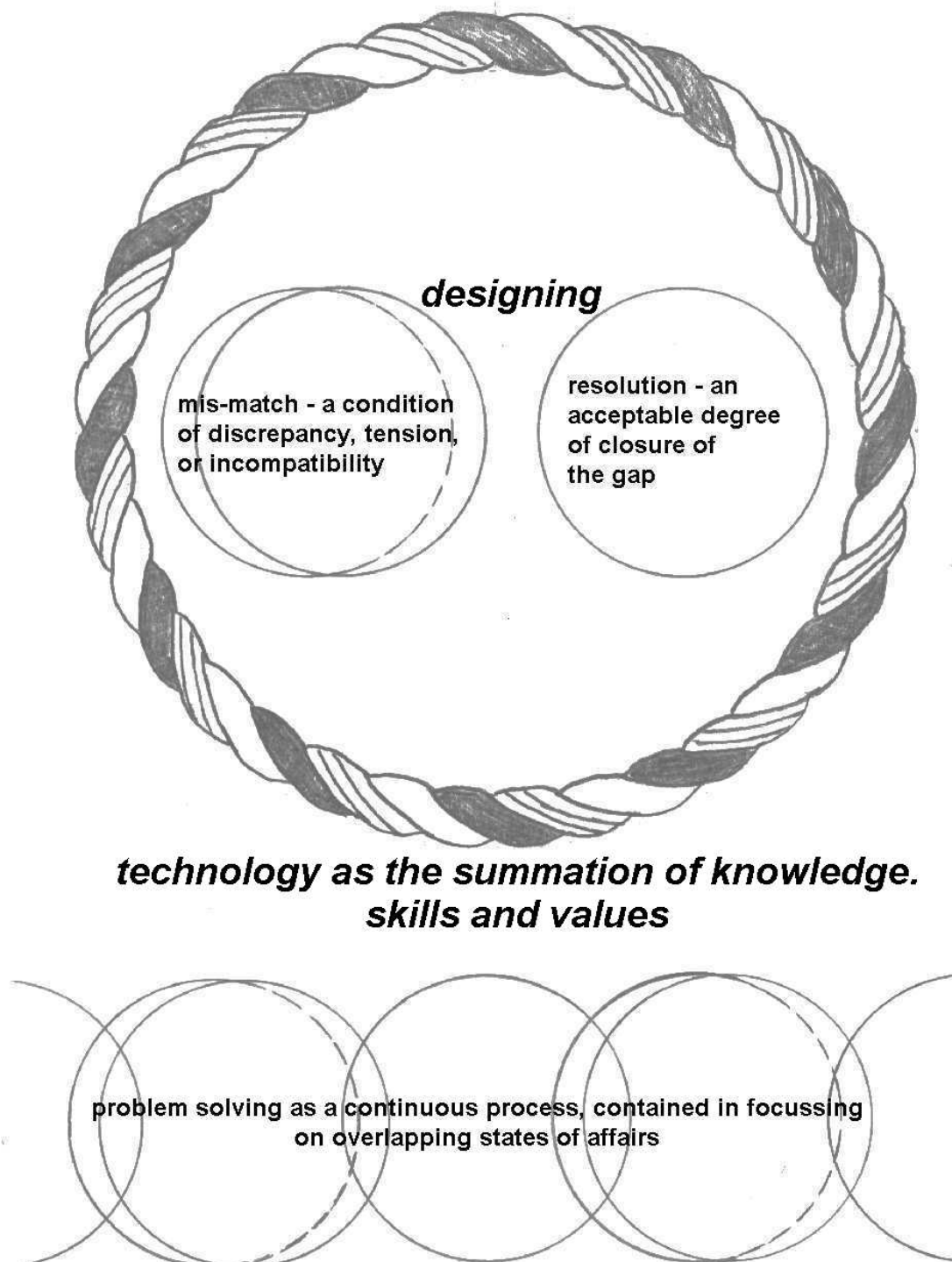


Figure 1: A model of technology for design.

Design and technology curricula have traditionally aspired to enable students to access the technology required for their designing at the point of need; students are then learning ‘technology for design’ through designing. There are sound pedagogical grounds for some aspects of technology for design to be taught and learnt before starting associated design projects (Norman, 1999). Further support for this view can be found from evolved good practice in relation to ‘focused practical tasks’ in the UK National Curriculum Technology. This recognition, particularly when combined with considerations of the high resource cost of ‘learning by doing’, has led to pressure on the perceived value of designing and making as a mode of learning. This is evident in the recent proposals for the revision of design and technology at 16 plus in the UK where ‘product analysis’ is being given ever-greater prominence. Product analysis can play an important supporting role for designing and making, but it is not an equivalent activity.

Some research evidence

An aspect of a research project, which was supervised by the author and completed at Loughborough University between 1995 and 1999, concerned the design and development of a polymer acoustic guitar. This was one aspect of a PhD research project that concerned the attention paid by industrial designers to materials and manufacturing processes (Pedgley, 1999). It was established prior to this study that ‘science’ could not provide any useful starting points. Relevant literature was searched but no test procedures or data were found concerning the vibration properties of polymers. The mathematical modelling of the vibration behaviour of a guitar would have been a major research task in itself. Consequently expert advice was sought in the belief that other forms of technological understanding could be accessed i.e. other ways of knowing.

Rob Armstrong, who is an internationally renowned luthier based in Coventry UK, collaborated in the development of the guitar. The outcomes are an innovative musical instrument and new technology that has recently been granted a patent (Armstrong *et al*, 1999). These developments were founded on Rob Armstrong’s acquired understanding of technology for guitar design; understanding which was gained through the designing and making of guitars. The development of this innovative technology has been fully documented, because Owain Pedgley kept a ‘diary of designing’ as one aspect of his research (Pedgley, 1997). The crucial sketch from this PhD study is shown in Figure 2 where Rob Armstrong was explaining the need for ‘getting air into the polymer’. The polymer Rob selected by ‘tapping’ samples and listening to the response was polycarbonate and a supplier of expanded polycarbonate sheet was eventually tracked down in Switzerland. Rob also explained the importance of ‘oneness’ in construction as being as crucial as the material chosen. It was these craft-based knowledge, skills and values that were the fundamental basis for this new technology. They were the essential technology that enabled the design to happen; and the hence the ‘technology for’ the design of the polymer guitar. There is no sense in which the polymer guitar’s origins can be seen as ‘applied science’. Other technologies were employed e.g. the expanded polycarbonate was extruded, the parts were bonded by a modern adhesive and CAD/CAM was employed to produce the mould. These were essential to enable the prototype to be made, but the designing was entirely dependent on Rob Armstrong’s expertise.

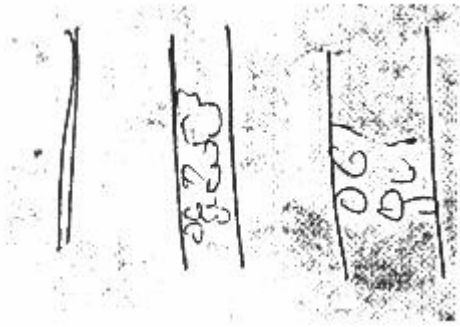


Figure 2: Rob Armstrong's original sketch of the structure required of a polymer soundboard.

Learning 'by doing' and teaching 'by showing'

The polymer acoustic guitar is a fully documented example of technological innovation that demonstrates the need for design and technology curricula to sustain 'learning by doing' and 'teaching by showing'. Some knowledge, skills and values can be captured and expressed through natural language, however others may be impossible to describe in this way (Daley, 1984, Polanyi, 1962). Visual descriptions are sometimes possible and Ferguson (1977) has charted the history of the use of nonverbal thought in technology. However, there are numerous instances of the difficulty of capturing human expertise.

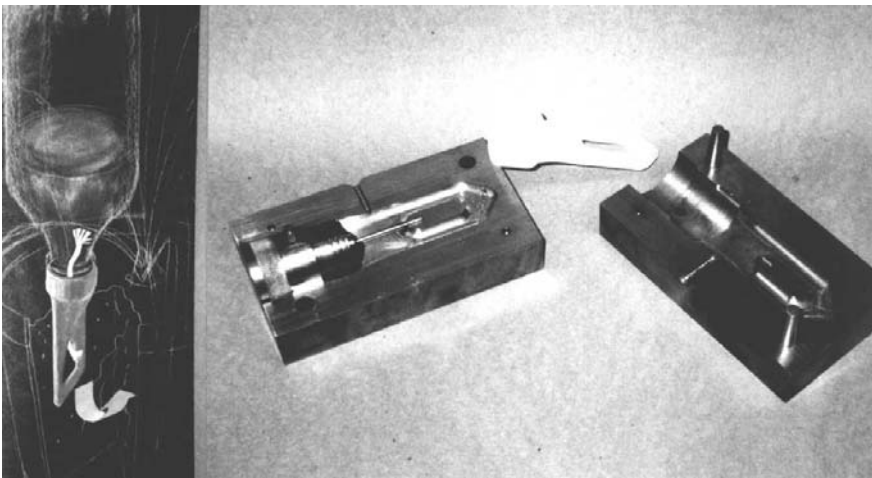
My industrial experience was as a research engineer in the welding industry, where the ability of a welder to control the root run in a pipe weld was well-known, as was the inability of apparently sophisticated machines to do the same (at least in the early 1980s when I returned to secondary teaching). Skilled welders can cope with heat build-up as the joint is completed, misalignment, tack welds and variations in fit-up with apparent ease, but despite much research there has been slow progress on the development of machines capable of doing the same. Researchers have attempted to establish what the welders saw, heard or 'sensed' and how they adapted their technique to keep the weld bead width constant. However, what was happening was not evident from films or tapes. The welders were, of course, unaware of what they were doing and unable to explain it in words; nevertheless a skilled welder could soon show an apprentice. Such 'teaching by showing' is normal practice in these circumstances. Adults teach their children to ride bicycles by showing them how and providing support in the early stages of the experience. Having procedural knowledge about riding a bicycle ('knowing that') is not the essential foundation for enabling action; it is 'knowing how' that counts (Ryle, 1949). It is, in fact, possible for someone to know why a bicycle works without knowing how to ride one at all. It is equally possible for a rider to know how to stay upright, but to be quite unable to explain why. These are rather different matters.

Some pedagogical implications

In relation to teaching and learning, the issues in my experience essentially relate to cognitive modelling; the modelling of design ideas in the 'mind's eye' (Baynes and Roberts, 1984). If 'technology for design' can be easily represented as an image then it can be taught at the point of need (i.e. through designing). If, on the other hand, the necessary technology for design must be represented mathematically, then it must be learnt first in order to facilitate cognitive modelling (Norman, 1999). Examples of my teaching of technology for design 'through designing' to undergraduates are shown in Figures 3a–3c.



(a) Nutcrackers (Year 1)



(b) Injection mould tools (Year 2)



(c) Products from recycled polymers (Year 2 and Year 3)

Figure 3: Examples of the teaching of technology for design 'through designing' to Industrial Design and Technology undergraduates at Loughborough University.

© Eddie Norman, Department of Design and Technology, Loughborough University, 1999

I also teach technological areas where prior learning is essential e.g. the analysis of structures (Norman, 1997a). Circumstantial evidence for similar conclusions can be found in the general content of engineering courses. It tends to be technologies such as electronics, mechanics, thermodynamics, fluid mechanics and stress analysis that are taught. Materials and manufacturing technologies are often left to 'graduate apprenticeships'. Essentially the same theoretical position is embodied in the textbook *Advanced Design and Technology* to which I contributed in 1990. The textbook discusses designing and includes details concerning selected technologies. The materials section deals with the more scientific and industrial aspects, but not workshop practice (a more detailed discussion can be found in Norman, 1997b). It is assumed that the practical working of materials is better taught 'by showing' and learnt 'by doing'.

The crucial concern of this paper is to demonstrate the need for design and technology teachers to sustain the teaching and learning of technology for design through designing and making. However, it has also highlighted the need for some technologies to be taught prior to designing, if they are to be effectively exploited. I teach undergraduates, but I believe that similar guiding principles apply to the teaching of younger students. In order to provide an opportunity for secondary teachers to pursue similar strategies, I co-authored a photocopiable resource pack on *Kites* for Key Stage 3 (Norman and Cubitt, 1999). Figure 4 shows the diagram included to communicate the technology required for a particular kind of kite. This was intended as a focused practical task through which pupils would learn technology for kite design.

Of course the central feature of the resource pack is a design and make assignment and the final section contains IDEAS (investigating, disassembling and evaluating familiar products and applications) and extension tasks. These contain worksheets relating to the testing of materials and components, analysing structures, the science of kite flying and the use of mathematics and information and communications technology (ICT) in relation to kite design. These are the more 'technical' areas that might need specific teaching if they are to be used by pupils when designing. Figure 5 shows perhaps the most 'ambitious' science-related worksheet contained in the resource pack. This is intended to represent visually a model of the forces acting on the kite so that students can understand one of the golden rules of kite flying (that the line should be attached so that when pulled it acts above the kite's centre of gravity).

SC 4 **The forces acting on a kite**

The model shown below will describe adequately the forces acting on a kite in a strong wind, i.e. where they are very large. The pressure drag, P , which acts perpendicular to the surface, is equal and opposite to the force in the line, T .

Measure T with a Newton meter

You might think that the value of the lift force would be quite near to the weight of the kite, but you have to remember that it has to lift the line as well. Even if you take this into account, you might still find that there is an error. This is because the forces acting on a kite are a little more complicated than the simple 'strong winds' model.

It is hard to calculate the values, but the cause of the error is the friction drag, F , which acts along the surface of the kite. You should, however, be able to see why one of the golden rules of kite flying is to attach the line so that when pulled it acts above the kite's centre of gravity. The combined action of T and P tends to turn the kite anticlockwise, and it is the effect of the weight that stops this happening.

Wind

P = the pressure drag
 F = the friction drag
 T = the tension or pull in the line
 Mg = the weight of the line

TASK 4

Measure the force on the line (T) with a Newton meter. This value can now be used for the pressure drag (P), as they are equal.

Calculate or estimate the angle at which your kite was flying (see worksheet M2, or you can assume 15°) and now, on graph paper, draw to scale a line representing P at this angle (75° to the horizontal). By either drawing the rectangle or triangle of forces as shown, you can now find the lift and drag forces acting on the kite. The vertical measurement represents L (the lift) and the horizontal represents D (the drag).

Figure 4: A focused practical task through which pupils can learn technology for kite design.

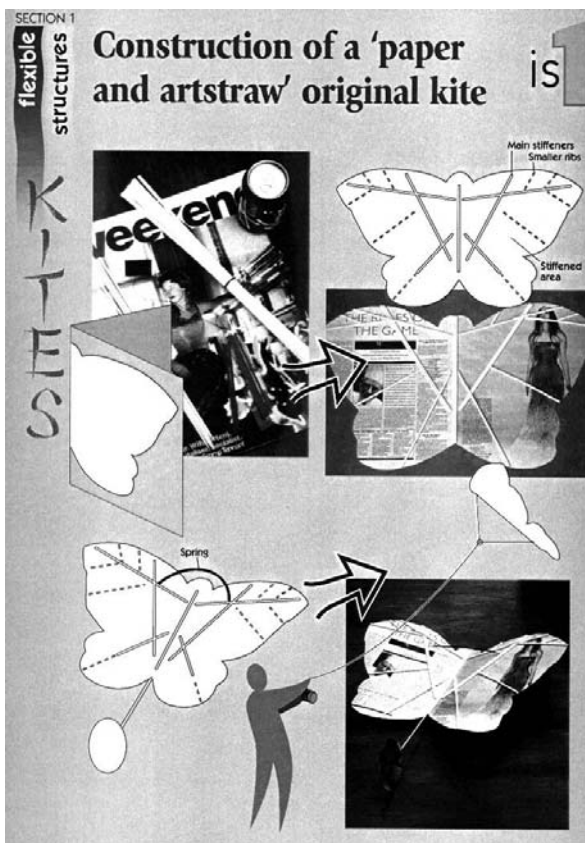


Figure 5: The forces acting on a kite and one of the golden rules of kite flying.

These ideas concerning good practice in design and technology education are, as yet, unproven, but I believe that there is sufficient evidence to justify writing this paper for the Design and Technology Millennium Conference. The uncovering and clear communication of the principles that underpin good practice in design and technology education is a vital concern for research and curriculum development in the next century.

References

- Archer, B., Badness, K., Langdon, R. and Roberts, P. (eds) (1979) *Design in General Education*, London: Royal College of Art
- Armstrong, R., Pedgley, O.F. and Norman, E.W.L. (1999) *Acoustic Device (Patent)*, Patent Number GB99 19922.6
- Baynes, K. and Roberts, P.H. (1984) 'Design Education: the Basic Issues' in Langdon, R., Baynes, K. and Roberts, P.H. (eds) *Design Policy: Design Education*, London: The Design Council
- Daley, J. (1984) 'Design Creativity and the Understanding of Objects' in Cross, N. (ed) *Developments in Design Methodology*, John Wiley
- Ferguson, E.S. (1977) 'The Mind's Eye: Nonverbal Thought in Technology', *Science* 197, 4306, 827–836
- Hicks, G. *et al* (1982) *Understanding Design and Technology*, Assessment of Performance Unit
- Layton, D. (1993) *Technology's Challenge to Science Education*, Buckingham: Open University Press
- Norman, E.W.L., Riley, J.L., Whittaker, M. and Urry S.A. (1990) *Advanced Design and Technology*, Essex: Longman
- Norman, E.W.L. (1997a) 'Towards the Capture of Design Intelligence – Independent Learning Materials and Calculation Software for the Analysis of Structures' in Smith, J.S. (ed) *IDATER 97*, 196–204, Loughborough: Loughborough University
- Norman, E.W.L. (1997b) 'Materials and Processes within A/AS-level Design and Technology: a Study of Implementation', *The Journal of Design and Technology Education*, 2, 3, 264–273, Wellesbourne: DATA
- Norman, E.W.L. (1998) 'The Nature of Technology for Design', *International Journal of Technology and Design Education*, 8, 1, 67–87, Stoke-on-Trent: Trentham Books
- Norman, E.W.L. (1999) 'Technology for Design: Cognitive Mismatches and their Implications for Good Practice', *The Journal of Design and Technology Education*, 4, 1, 32–39, Wellesbourne: DATA
- Norman, E.W.L. and Cubitt, J.L. (1999) *Key Stage 3 Design and Technology: Kites – Flexible Structures*, Deddington: Phillip Allan
- Pedgley, O.F. (1997) 'Towards a Method for Documenting Industrial Design Activity from the Designer's Perspective'. In Smith, J.S. (ed) *IDATER 97*, 217–222 Loughborough: Loughborough University
- Pedgley, O.F. (1999) *Industrial Designers' Attention to Materials and Manufacturing Processes: Analysis at Macroscopic and Microscopic Levels*, PhD Thesis, Loughborough University
- Polanyi, M. (1962) 'Tacit Knowing: its Bearing on some Problems of Philosophy', *Reviews of Modern Physics*, 34, 4, 601–616
- Roberts P.H. (1992) 'Of Models, Modelling and Design: an Applied Philosophical Enquiry'. In *Modelling: the Language of Designing*, Design: Occasional Paper No.1, Loughborough: Department of Design and Technology, Loughborough University
- Roberts, P.H. and Norman, E.W.L. (1999) 'Models of Design and Technology and their Significance for Research and Curriculum Development', *The Journal of Design and Technology Education*, 4, 2, 124–131, Wellesbourne: DATA
- Ryle, G. (1949) *The Concept of Mind*, London: Hutchinson